1. The following is *not* true concerning electric charge.

A. A charge can create a magnetic field.

B. Two kinds of charge exist in nature.

C. Charge can take on any value.

D. Charge is conserved.

E. A charge can create an electric field.

2. A -10^{-5}C point charge is located at the origin of a coordinate system. A $+10^{-5}$C point charge is located 0.5m from the charge at the origin and the line joining the charges is inclined at an angle of 30° relative to the x-axis as shown in the diagram. The force on the charge at the origin is closest to

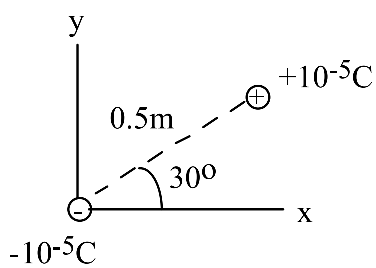
A. (10**i** + 5.6**j**) N.

B. (5.6**i** + 10**j**) N.

C. (3.6**i** + 3.6**j**) N.

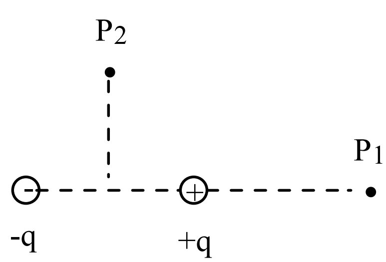
D. (2.0**i** + 1.2**j**) N.

E. (3.1**i** + 1.8**j**) N.



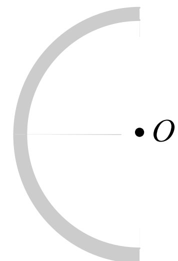
3. Consider the electric dipole shown in the diagram. The row in the table that shows the best direction of the electric field at point P_1 and the best direction of the electric field at point P_2 are

Row	Direction of **E** at P_1	Direction of **E** at P_2
A	→	←
B	→	→
C	←	←
D	←	→
E	↑	↓



4. A uniformly charged insulating rod is bent into the shape of a semicircle as shown. If the rod has a total charge of +*Q* and a radius *R*, the magnitude of the electric field at *O*, the center of the semicircle is

A. $k_e \dfrac{Q}{R^2}$.   B. $k_e \dfrac{2Q}{\pi R^2}$ C. $k_e \dfrac{Q}{2R^2}$ D. $k_e \dfrac{Q}{\pi R^2}$ E. $k_e \dfrac{2Q}{R^2}$



5. The shaded area below represents the cross section of a thick, solid, spherical conducting shell that has a total charge of +10C. The conductor is hollow and a +3C charge exists at the center of the cavity. The solid line at the middle of the conductor represents the cross section of a spherical gaussian surface. The net (total) electric flux through the gaussian surface is

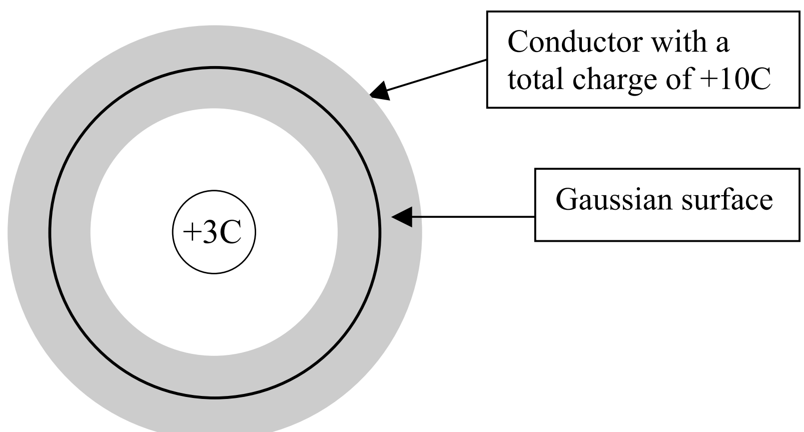
A. 0.

B. $+\dfrac{3}{\varepsilon_o}$.

C. $+\dfrac{7}{\varepsilon_o}$.

D. $+\dfrac{10}{\varepsilon_o}$.

E. $+\dfrac{13}{\varepsilon_o}$.



6. Three charges are located at the corners of a square of side 0.5m. Point P is located at the fourth corner of the square. (1nC=10^{-9}C) The electric potential at point P is closest to

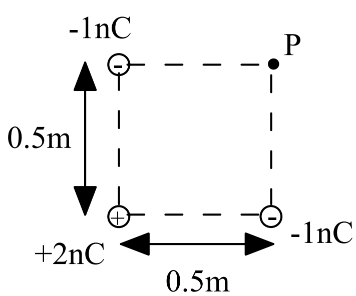
A. 0.

B. -10.5 V.

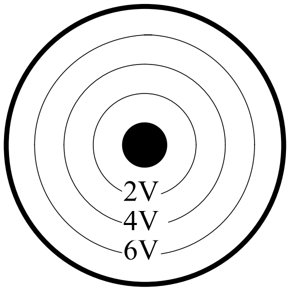
C. -15.2 V.

D. -21.1 V.

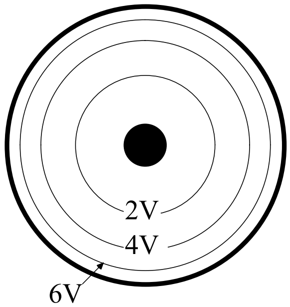
E. -31.6 V.



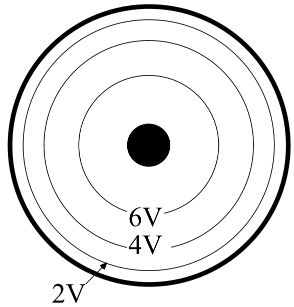
7. A conducting wire is coaxial with a larger, conducting cylindrical shell. A battery is connected to the conductors so that there is an electric field that is *radially outward* between the conductors. If the central dark spot represents the wire and the dark outer circle represents the shell, the best representation of the equipotentials associated with this configuration is



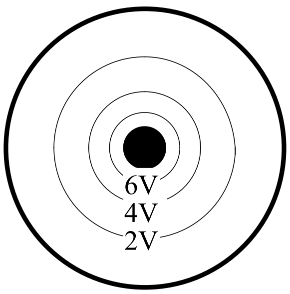
A.



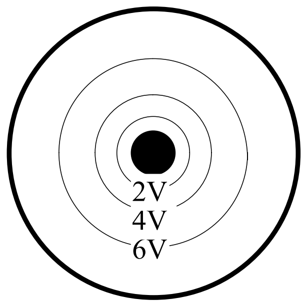
B.



C.

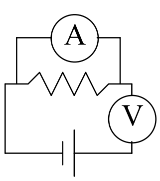


D.

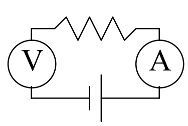


E.

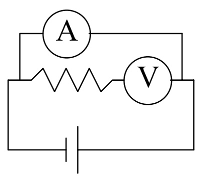
8. A circuit consists of a battery and a resistor. The following sketch shows the best way to connect a voltmeter and ammeter so that their readings can be used to calculate the resistance of the resistor.



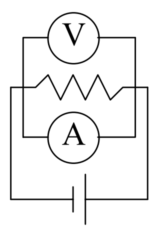
A.



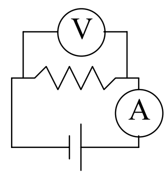
B.



C.



D.

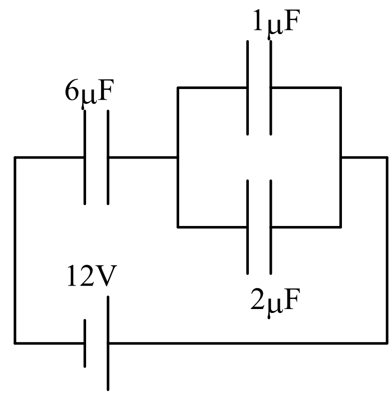


E.

9. Suppose that the experiment described in the previous problem is carried out and the results of the measurements are that V = (12.0 ± 0.4) V and I = (2.0 ± 0.2) A. The resistance is best represented by

A. (6.0 ± 0.6) Ω. B. (6.0 ± 0.2) Ω. C. (6.0 ± 0.8) Ω. D. (6.0 ± 0.1) Ω. E. (6.0 ± 0.4) Ω.

10. Consider the capacitors shown in the diagram. ($1\mu F=10^{-6}$ F) The charge on the $1\mu F$ capacitor is closest to



A. 8 μC.

B. 4 μC.

C. 24 μC.

D. 16 μC.

E. 12 μC.

11. A parallel plate capacitor is charged with a battery. The battery is then disconnected and a slab of insulating material (a dielectric) is inserted between the plates. As the dielectric is inserted,

A. the capacitance increases, the voltage increases and the stored energy increases.

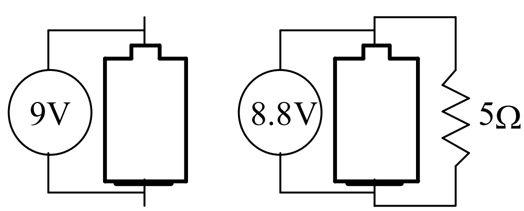
B. the capacitance decreases, the voltage increases and the stored energy increases.

C. the capacitance increases, the voltage decreases and the stored energy increases.

D. the capacitance increases, the voltage decreases and the stored energy decreases.

E. the capacitance decreases, the voltage decreases and the stored energy decreases.

12. A battery has an emf of 9V. (A perfect voltmeter gives a reading of 9V across the battery when the battery is not part of a circuit.) When a 5 Ω resistor is connected across the battery, the voltage across the battery (and also across the resistor) is 8.8V. The internal resistance of the battery is closest to



A. 0.11 Ω.

B. 0.35 Ω.

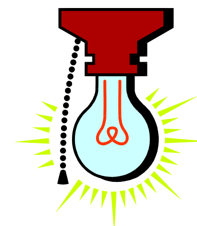
C. 0.44 Ω.

D. 0.23 Ω.

E. 0.66 Ω.

The next three problems deal with the filament in a light bulb. The filament has a cross sectional area of 10^{-6} m^2 and is 0.02m long and the dimensions are assumed to be constant (independent of temperature). The temperature coefficient of resistivity is $5x10^{-3}(^oC)^{-1}$. When the filament is glowing, there is a current of 2A in the filament, the electrons have a drift velocity of magnitude $3x10^{-4}$ m/s and the temperature of the filament is 1020^{o}C.

13. When the filament is glowing, the concentration of electrons in the filament is closest to



A. $2.1x10^{28}$ electrons/m^3.

B. $4.2x10^{28}$ electrons/m^3.

C. $8.5x10^{28}$ electrons/m^3.

D. $5.2x10^{27}$ electrons/m^3.

E. $1.5x10^{29}$ electrons/m^3.

14. If the light bulb is a 100W light bulb, when the filament is glowing the resistance of the filament is closest to

A. 17.9 Ω.

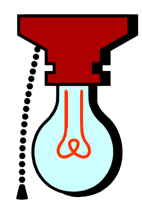
B. 12.3 Ω.

C. 20.0 Ω.

D. 6.2 Ω.

E. 25.0 Ω.

15. When the filament is at room temperature (T=20^{o}C) and hence *not* glowing, the resistance of the filament is closest to



A. 2 times what it was when it was glowing.

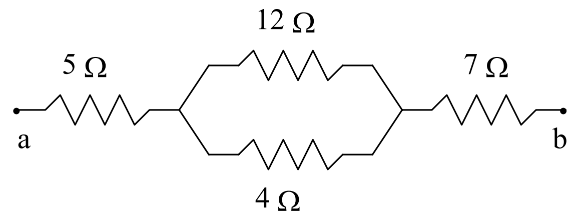
B. 6 times what it was when it was glowing.

C. $\frac{1}{2}$ of what it was when it was glowing.

D. $\frac{1}{6}$ of what it was when it was glowing.

E. the same as it was when it was glowing.

16. For the resistor network shown at the right, the equivalent resistance between points a and b is closest to



A. 12 Ω.

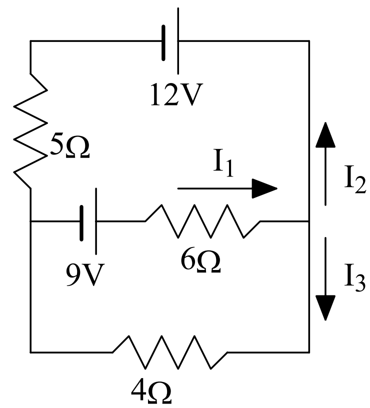
B. 28 Ω.

C. 15 Ω.

D. 16 Ω.

E. 24 Ω.

17. For the circuit and currents given in the diagram, the correct set of independent equations that can be used to solve for I_1, I_2 and I_3 is



A. $I_1 = I_2 + I_3$, $3 + 6I_1 - 5I_2 = 0$, $9 - 6I_1 + 4I_3 = 0$.

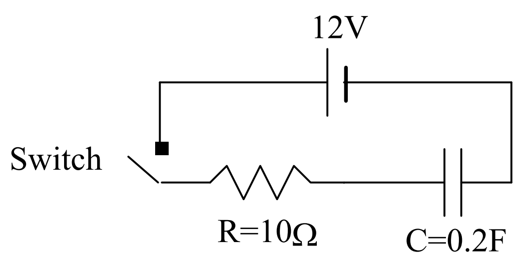
B. $I_1 = I_2 + I_3$, $3 + 6I_1 + 5I_2 = 0$, $9 - 6I_1 - 4I_3 = 0$.

C. $I_1 + I_2 = I_3$, $3 - 6I_1 - 5I_2 = 0$, $9 - 6I_1 + 4I_3 = 0$.

D. $I_1 + I_2 = I_3$, $3 + 6I_1 - 5I_2 = 0$, $9 - 6I_1 - 4I_3 = 0$.

E. $I_1 = I_2 + I_3$, $3 - 6I_1 + 5I_2 = 0$, $9 + 6I_1 + 4I_3 = 0$.

The next two problems deal with the series RC circuit shown below. The capacitor is initially uncharged and the switch is closed at t=0.



18. At t=4s, the current in the resistor is closest to

A. 1.20 A.

B. 0.60 A.

C. 0.27 A.

D. 0.16 A.

E. 0.022 A.

19. When the capacitor is fully charged ($t=\infty$), the energy stored in the capacitor is closest to

A. 2 J. B. 5 J. C. 8 J. D. 11 J. E. 14 J.

20. At some instant, a –3C charge is traveling in the x-y plane with a speed of 50m/s at an angle of 30^o with respect to the x-axis as shown in the diagram. There is a uniform magnetic field of magnitude 0.1T pointing in the positive x-direction. The positive z-axis is out of the paper. The magnetic force on the –3C charge is closest to

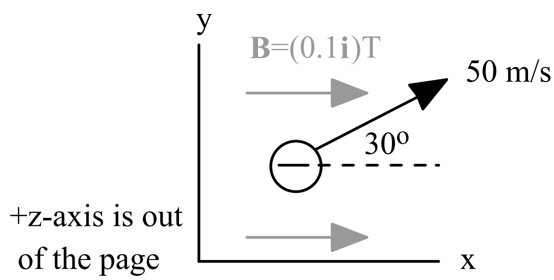
A. -(5.2**k**) N.

B. -(3.0**k**) N.

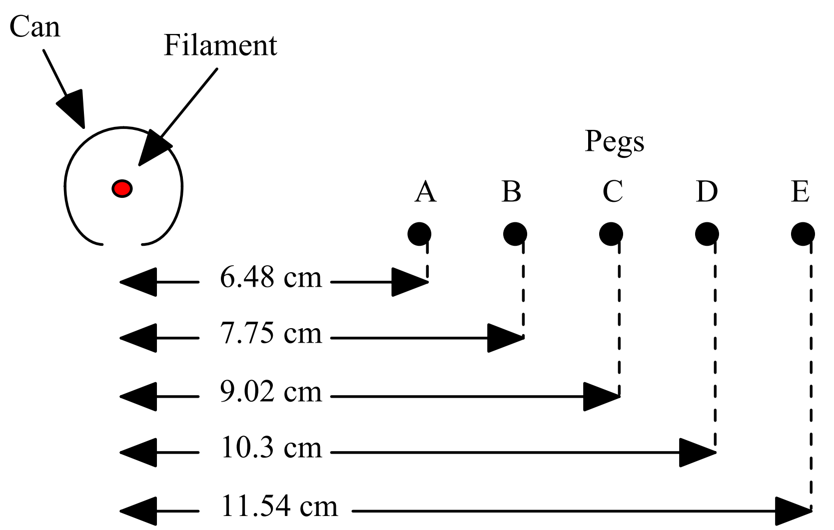
C. +(7.5**k**) N.

D. +(13**k**) N.

E. +(22.5**k**) N.



The next two problems deal with the Magnetic Force Laboratory where electrons are accelerated through a potential difference (voltage) and enter a region of constant, uniform magnetic field. A cross section of the top of the equipment is shown in the following diagram. The electrons are emitted by the filament and accelerated because there is a potential difference (voltage) between the filament and the can. The electrons exit the bottom of the can with a speed of 3×10^6 m/s. The magnetic field has a magnitude of 3×10^{-4} T and is in such a direction as to deflect the electrons so that they strike a peg.



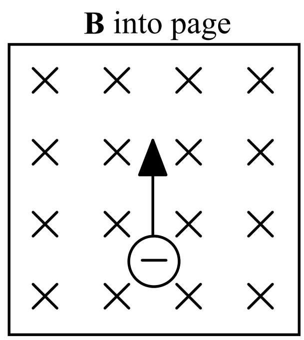
21. The magnitude of the potential difference (voltage) between the can and the filament is closest to

A. 20 V. B. 25 V. C. 30 V. D. 35 V. E. 40 V.

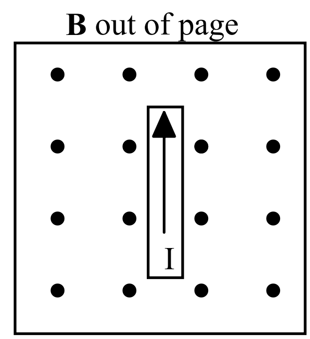
22. The electrons strike peg

A. A. B. B. C. C. D. D. E. E.

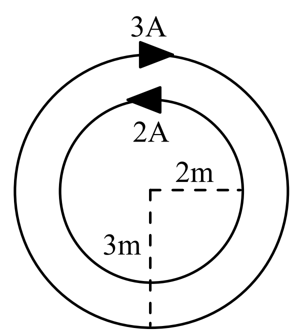
23. The following situations are separate. In the picture on the left, an electron has a velocity up in the plane of the paper in a constant magnetic field into the page. In the picture on the right, there is a segment of a wire with a current up in a constant magnetic field out of the page. The row in the following table that correctly gives the direction of the magnetic force on the electron and the direction of the magnetic force on the current is



Row	Direction of the force on the electron	Direction of the force on the current
A	→	←
B	←	→
C	←	←
D	→	→
E	↑	↑



24. A circular loop of radius 3m carries a clockwise current of 3A. A circular loop in the same plane that has the same center has a radius of 2m and carries a counterclockwise current of 2A. The magnetic field at the center of the loops is



A. 0.

B. μ_o T out of the page.

C. μ_o T into the page.

D. $5\mu_o$ T out of the page.

E. $5\mu_o$ T into the page.

25. A circular loop of radius 2m and carrying a current of 2A is in a magnetic field **B**=0.3**i**T as shown below. Using the standard coordinate system (shown) the torque on the loop is closest to

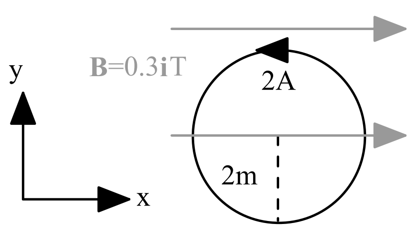
A. (15**j**) N-m.

B. (4.9**j**) N-m.

C. (7.5**j**) N-m.

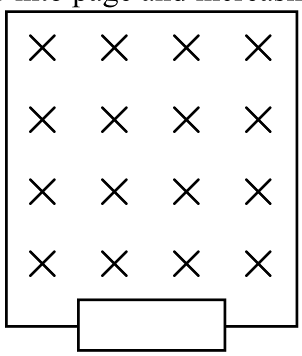
D. (3.3**i**) N-m.

E. 0.



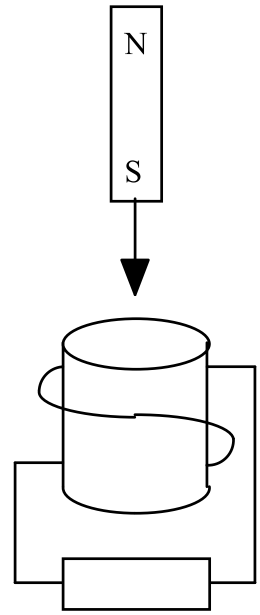
26. The following situations are separate. In the picture on the left, there is a *increasing* magnetic field (inside the loop) into the page. In the picture on the right, a magnet is moving toward a loop as shown. The row in the following table that correctly gives the direction (or status) of the current in each resistor is

B into page and increasing



Resistor 1

Row	Direction of the Current in Resistor 1	Direction of the Current in Resistor 2
A	→	→
B	←	→
C	→	←
D	←	←
E	The current is zero.	The current is zero.



Resistor 2

The next two problems are concerned with a tightly wound solenoid. The solenoid is 0.1 m long, has a cross sectional area of $0.05 m^2$ and has 100 turns. There is a current of 2A in the solenoid,

27. The magnitude of the magnetic field at the middle of the solenoid is closest to

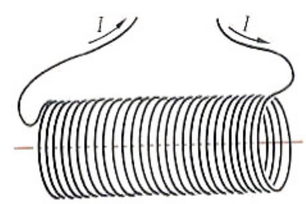
A. $8.1x10^{-4}$ T.

B. $2.5x10^{-3}$ T.

C. $1.3x10^{-4}$T.

D. $4.1x10^{-2}$ T.

E. $5.0x10^{-3}$ T.



28. The inductance of the solenoid is closest to

A. 0.071 H.

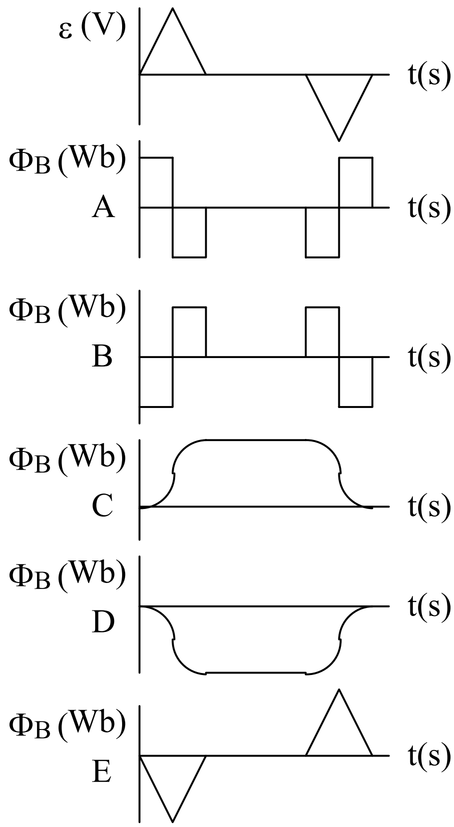
B. 0.045 H.

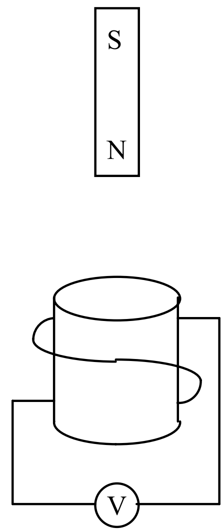
C. 0.025 H.

D. 0.0063 H.

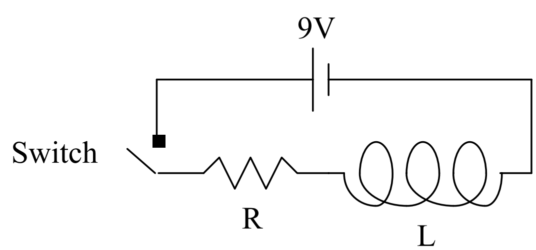
E. 0.0031 H.

29. A magnet is moved from a position far away from a coil to a position close to the coil, left there for a few seconds and finally returned to a position far away from the coil. The voltage vs. time across the coil and is shown in the first graph. The graph that best represents the flux vs. time in the coil is





The next two problems deal with the series RL circuit shown in the next diagram. R=6Ω and L=0.3H.



30. There is no current in the circuit before the switch is closed at t=0. The voltage across the resistor at t=0.03s is closest to

A. 9 V.

B. 2 V.

C. 5 V.

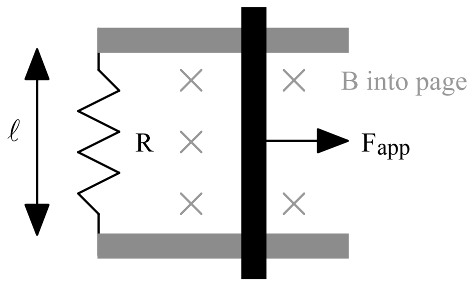
D. 6 V.

E. 4 V.

31. When the current is 0.82A, the energy stored in the inductor is closest to

A. 0.10 J. B. 0.15 J. C. 0.20 J. D. 0.25 J. E. 0.30 J.

32. Consider the arrangement shown in the diagram at the right. Assume that R=5Ω, ℓ=1.1m and a uniform 3T magnetic field is directed into the page. The speed at which the bar should be moved to produce a current of 0.3A in the resistor is closest to



A. 0.05 m/s.

B. 0.15 m/s.

C. 0.30 m/s.

D. 0.45 m/s.

E. 0.60 m/s.

33. The following is *not* one of Maxwell's equations

A. $\oint \mathbf{E} \bullet d\mathbf{s} = -\frac{d\Phi_B}{dt}$ B. $\oint \mathbf{B} \bullet d\mathbf{A} = 0$ C. $\oint \mathbf{E} \bullet d\mathbf{A} = \Phi_C$

D. $\oint \mathbf{B} \bullet d\mathbf{s} = \mu_o I + \varepsilon_o \mu_o \frac{d\Phi_E}{dt}$ E. $\oint \mathbf{E} \bullet d\mathbf{A} = \frac{Q}{\varepsilon_o}$

34. An electric field of magnitude 200 V/m and directed into the page is confined to a circular area of radius 0.2m. The field is increasing at a rate of 15 V/(m-s). The displacement current associated with the electric field is closest to

A. 1.7×10^{-11} A into the page.

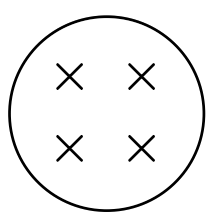
B. 3.3×10^{-11} A into the page.

C. 5.3×10^{-11} A out of the page.

D. 7.0×10^{-11} A out of the page.

E. 0.

E into the page and increasing



The next two problems deal with an electromagnetic wave in a material where the electric field has a y-component only and, in SI units, is given by

$$E_y = 50 \sin(1.2\text{x}10^7 x - 1.8\text{x}10^{15} t)$$

35. The speed and wavelength (1nm=10^{-9}m) of the wave are closest to

A. $1.8\text{x}10^8$ m/s and 524 nm.

B. $1.5\text{x}10^8$ m/s and 524 nm.

C. $1.2\text{x}10^8$ m/s and 650 nm.

D. $1.8\text{x}10^8$ m/s and 483 nm.

E. $1.5\text{x}10^8$ m/s and 483 nm.

36. The average value of the Poynting vector (intensity of the wave) is closest to

A. 2.5 W/m^2.

B. 3.3 W/m^2.

C. 4.3 W/m^2.

D. 5.1 W/m^2.

E. 6.7 W/m^2.

37. When unpolarized light is passed through two polarizing filters in succession, its intensity is decreased by 80%. The angle, θ, between the transmission axes of the filters is

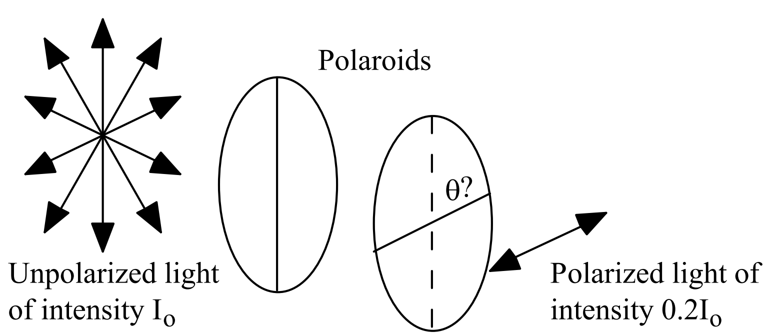
A. 78.5°.

B. 63.4°.

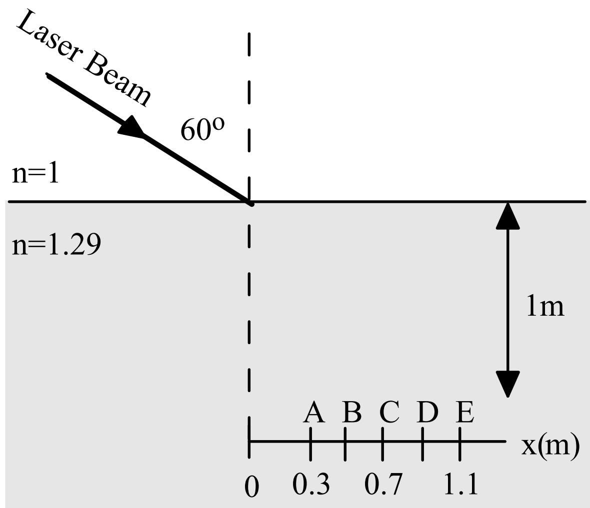
C. 26.6°.

D. 36.9°.

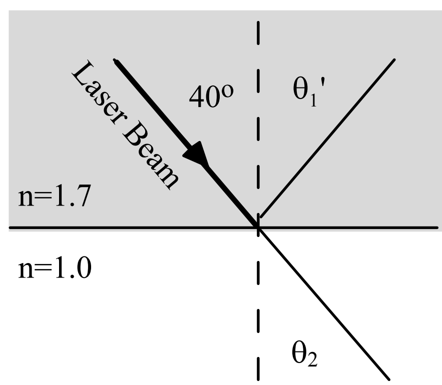
E. 50.8°.



38. A laser beam in air is incident on a material of refractive index 1.29 at an angle of 60° with respect to the normal (dashed line at x=0). The x-coordinates of the letters A, B, C, D and E are 0.3, 0.5, 0.7, 0.9 and 1.1m and each letter is 1.0m below the interface. The letter that the beam strikes is



39. A laser beam in a material of refractive index 1.7 is incident on air at an angle of 40° with respect to the normal. The following statement best describes the beam when it strikes the interface.



A. The beam is totally reflected at an angle of $\theta_1' = 22^\circ$.

B. The beam is totally reflected at an angle of $\theta_1' = 36^\circ$.

C. The beam is totally reflected at an angle of $\theta_1' = 40^\circ$.

D. The beam is mostly refracted at an angle of $\theta_2 = 36^\circ$.

E. The beam is mostly refracted at an angle of $\theta_2 = 22^\circ$.

40. In the previous problem, when the laser beam is traveling in the material with a refractive index of 1.7 the speed of the laser beam is closest to

A. $3.0\text{x}10^8$ m/s.

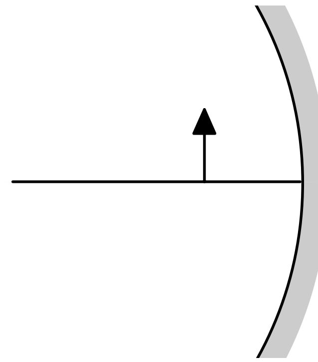
B. $1.8\text{x}10^8$ m/s.

C. $8.4\text{x}10^7$ m/s.

D. $2.3\text{x}10^8$ m/s.

E. $5.1\text{x}10^8$ m/s.

41. An object (arrow) is placed 10 cm in front of a spherical, concave mirror of radius of curvature of +30 cm. The image of the object is



A. real, upright and smaller than the object.

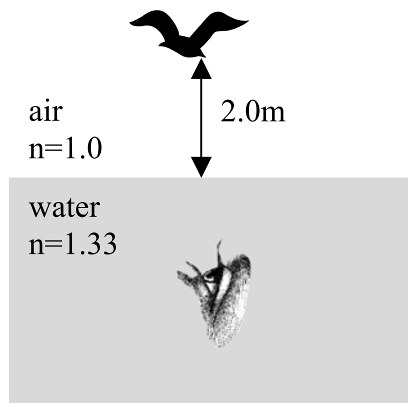
B. virtual, inverted and smaller than the object.

C. real, inverted and larger than the object.

D. virtual, upright and smaller than the object.

E. virtual, upright and larger than the object.

42. A seagull is flying 2.0m above the surface of the ocean. The following best describes where the seagull appears to be if viewed from below the surface of the ocean? The seagull appears to be



A. 2.7 m above the surface of the water.

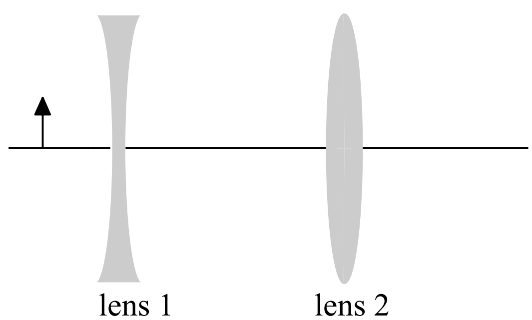
B. 1.5 m above the surface of the water.

C. 2.7 m below the surface of the water.

D. 1.5 m below the surface of the water.

E. 2.0 m above the surface of the water.

43. A real object is 10 cm to the left of a biconcave lens (lens 1) with a focal length of –20 cm. A biconvex lens (lens 2) with a focal length of +15 cm is 30 cm to the right of lens 1. The position of the final image formed by the combination is closest to



A. 10.6 cm to the right of lens 2.

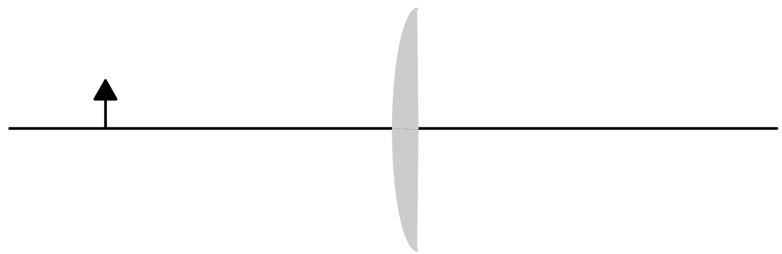
B. 10.6 cm to the right of lens 1.

C. 6.7 cm to the left of lens 2.

D. 25.4 cm to the right of lens 1.

E. 25.4 cm to the right of lens 2.

The following two problems are concerned with the thin, plano-convex lens shown in the diagram. (The front surface is curved and the back surface is flat.) The lens has a focal length of +20 cm and is made using a material with a refractive index of 1.5.



44. The radius of curvature of the front surface of the lens is closest to

A. 20 cm.

B. 30 cm.

C. 10 cm.

D. 60 cm.

E. 40 cm.

45. If a real object is 60 cm to the left of the lens, the image formed by the lens is best described as

A. upright and 30 cm to the left of the lens.

B. inverted and 120 cm to the right of the lens.

C. upright and 120 cm to the left of the lens.

D. inverted and 30 cm to the right of the lens.

E. upright and 20 cm to the right of the lens.

46. A Young's interference experiment is performed with monochromatic light of wavelength 632.8 nm. In the interference pattern on a screen 3.0m away from the slits, the second minimum is 5 mm away from the center of the pattern. The separation between the slits is closest to

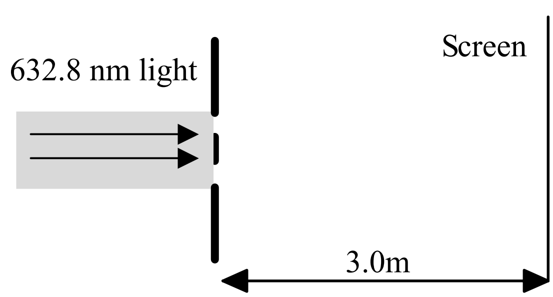
A. 1.21 mm.

B. 0.57 mm.

C. 0.76 mm.

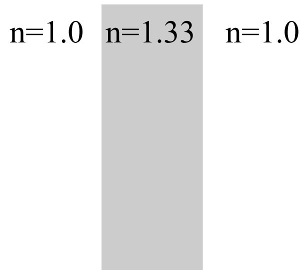
D. 0.99 mm.

E. 0.36 mm.



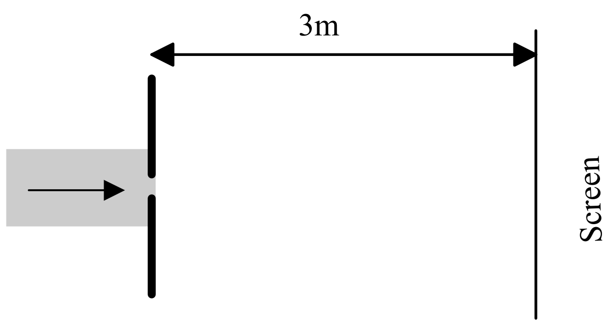
47. A soap bubble of refractive index 1.33 is floating in air. A cross section of a portion of the bubble wall is shown in the diagram. If a wavelength of 600 nm is strongly reflected perpendicular to the surface of the bubble, the thickness of the bubble wall is closest to

A. 152 nm.
B. 189 nm.
C. 226 nm.
D. 279 nm.
E. 338 nm.



48. Light of wavelength 632 nm is incident on a single slit. The distance from the slit to a screen is 3m. If the distance from the first minimum on one side of the center of the diffraction pattern to the first minimum on the other side is 8 mm, the width of the slit is closest to

A. 0.22 mm.
B. 0.31 mm.
C. 0.47 mm.
D. 0.59 mm.
E. 0.66 mm.



49. A boat has lights on a mast that are 1m apart. The dominant wavelength in the lights is 600 nm. The pupil in a person's eye has an opening of 1 mm. For simplicity, we will assume that the fluid in the eye has a refractive index of 1. If the boat is closer, the person sees two lights on the mast. If the boat is farther away, the person sees only one light on the mast. The best value for the distance of the boat from the person is

A. 1.4 km.
B. 1.2 km.
C. 2.0 km.
D. 1.6 km.
E. 1.8 km.

50. A beam of light is incident on a diffraction grating that has 600 lines per millimeter. The second order maximum occurs at a distance of 0.7m from the center of a screen that is 1.0m from the grating. The wavelength of the light is closest to

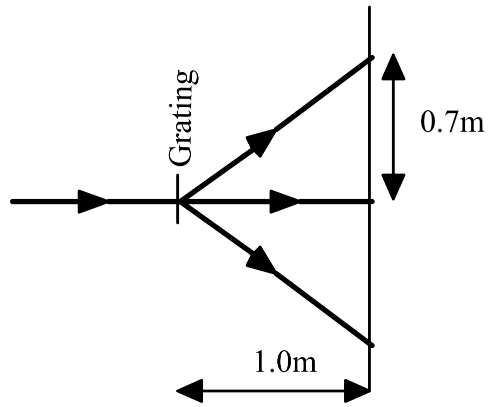
A. 478 nm.

B. 613 nm.

C. 574 nm.

D. 689 nm.

E. 542 nm.



51. The version of this exam that you have (from the cover page) is

A. version A.

B. version B.

52. The letter at the top of this page is

A. A.

B. B.

Note: When you have finished working on the exam, obtain a SCANTRON answer sheet from your instructor and proceed as follows.

1. Please fill in the top of the answer sheet with your alpha code and section number. (There is an example on the back of this exam.)

2. Please print your name and your instructor's name in the spaces on the right of the answer sheet. (There is an example on the back of this exam.)

3. Carefully transfer your answers from the exam to the "bubbles" on the answer sheet. IF you make a mistake and cannot erase cleanly, please get a new answer sheet from your instructor and start over.

4. Turn in the answer sheet, exam and scratch paper to your instructor.